AD-A192 399 AUTOMATIC LINE NETWORK EXTRACTION FROM AERIAL IMAGERY OF URBAN AREAS THRO..(U) FORSCHUNGSINSTITUT FUER INFORMATIONS- VERARBEITUNG UND MUSTER - H KAZMIERCZAK 19 JAN 88 DAJA45-86-C-0049 F/G 8/2 1/1

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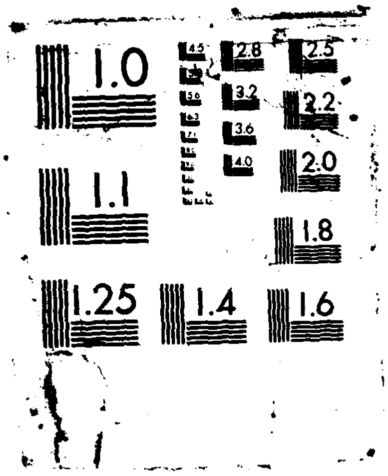
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Automatic Line Network Extraction from Aerial Imagery of Urban Areas through Knowledge-Based Image Analysis

Fourth Interim Report
January 19, 1988

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Principal Investigator: Prof. Dr.-Ing. H. Kazmierczak,
FIM,
Ettlingen, Germany

Present Status

During the past five months work has been concentrated on four topics, namely (1) further elaboration of the conceptual scheme for the automatic extraction of the traffic network from aerial images, (2) production of results at the iconic image analysis level, (3) the implementation of two segmentation procedures, (4) and investigation of a blackboard-oriented production system for image understanding (BPI) in the context of traffic network extraction.

1 Conceptual Scheme

Investigations of three different methods for the automatic extraction of the traffic network from aerial imagery of rural as well as urban areas have shown the strengths and weaknesses of these methods.

A method for the automatic extraction of line objects from large aerial images of prevailing rural areas [1,2] works successfully in this domain. However, when applied to images of urban areas, success and reliability of the method decrease remarkably due to the complex mixture of natural and man made objects at those locations. It seems to be impossible to solve this problem through specialized signal processing methods without incorporation of semantics, i.e. detailed modelling of prototypical objects and object arrangements to represent housing areas, plant areas, traffic areas, etc.

A next method we have examined is best described as knowledge-based approach for the analysis of aerial images [3]. In this approach image analysis is performed at three levels of abstraction, namely iconic or low-level image analysis, symbolic or medium-level image analysis, and semantic or high-level image analysis. Domain dependent knowledge about prototypical urban areas is incorporated via a semantic network. The method works well in urban areas that are not too complex, like the aerial image of Phoenix, Arizona. It can be anticipated that a more elaborated control mechanism combined with enhanced segmentation methods enable the system to process successfully even more complex images. However, depart from using enhanced segmentation, we decided not to follow this approach, because a third method we have investigated will promise reasonable results at lower cost.

This method uses a blackboard-oriented production system for image understanding [4,5]. Under the premise that the crossings of the traffic network can be detected, this method is able to extract the traffic network from aerial images of a complexity like the Bietigheim image (South-West Germany).

Our approach for the automatic extraction of the traffic network from aerial images consists of a combination of the three methods described above:

- Application of the signal processing method for road extraction in rural areas to get cues for the extraction of arterial roads at the boundaries

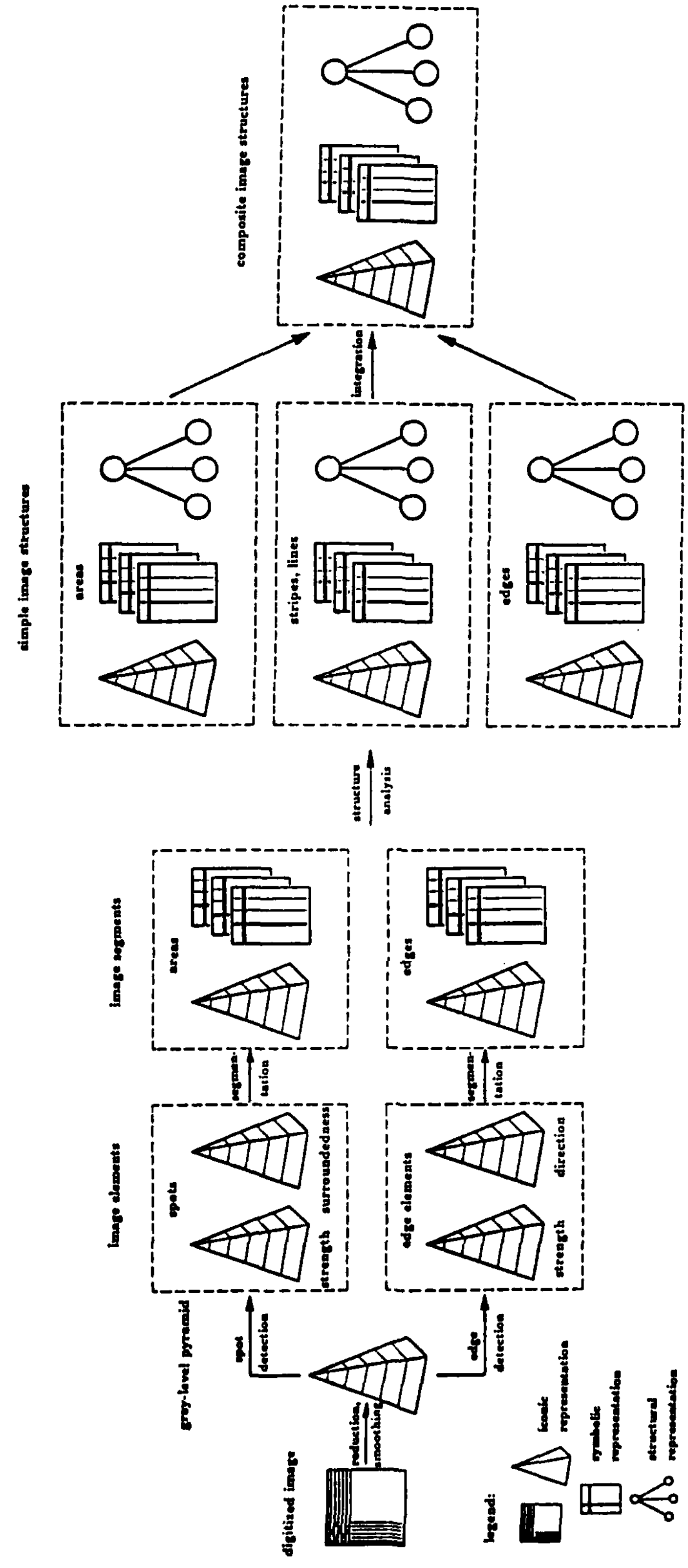


Figure 1: Iconic and symbolic image analysis levels

from rural to urban areas.

- Enhancement of the blackboard-oriented approach, using segmentation methods developed for the knowledge-based approach.

- Application of the enhanced blackboard-oriented approach to extract the traffic network within urban areas using the cues of arterial roads and crossings.

In the following we describe the iconic and symbolic image analysis levels carried out up to now (Fig. 1).

First, we compute from the digitized image a gray-level multi-resolution pyramid. Then we apply a spot-detector as well as an edge-detector to the gray-level pyramid, computing spots resp. edge elements. The original idea to implement also a line-detector has been modified; it is a significant improvement to detect lines at a later stage of image analysis, e.g. as adjacent anti-parallel edges.

At the symbolic image analysis level two segmentation procedures are at hand, computing area- resp. edge-like image segments.

Using the blackboard-oriented environment, image analysis proceeds by detecting regular arrangements and structures between image segments and image structures. At a first stage simple image structures are detected, e.g. by merging adjacent anti-parallel edges to lines or by merging short edges to longer ones, obeying the Gestalt principles of symmetry resp. good continuation. At a later stage of analysis interdependencies between structures are detected, e.g. parallelisms between neighboring lines. For that purpose we introduce two other sections in the conceptual scheme entitled "simple image structures" resp. "composite image structures".

2 Results of Spot- and Edge-Detection

As we have pointed out in our last report, low-level image analysis is done by applying competing knowledge-sources or experts. In particular we have implemented a spot-detector, and an edge-detector.

Figure 2 shows the gray-level pyramid of an urban scene. Figure 3 (upper part) shows the strength response of the spot-detector applied to the gray-level pyramid of figure 2. Fig. 3 (lower part) shows the surroundedness response of the spot-detector applied to the same scene. Strength response as well as surroundedness response are used by an appropriate segmentation procedure to obtain area-like segments of the input image.

To obtain edge-like segments, the response of an edge-detector is used. In our case we use the Sobel operator to detect edges. Nevertheless any edge-detector computing strength and direction responses of an edge can be used. Figure 4 (above) shows the strength response of the Sobel operator applied to

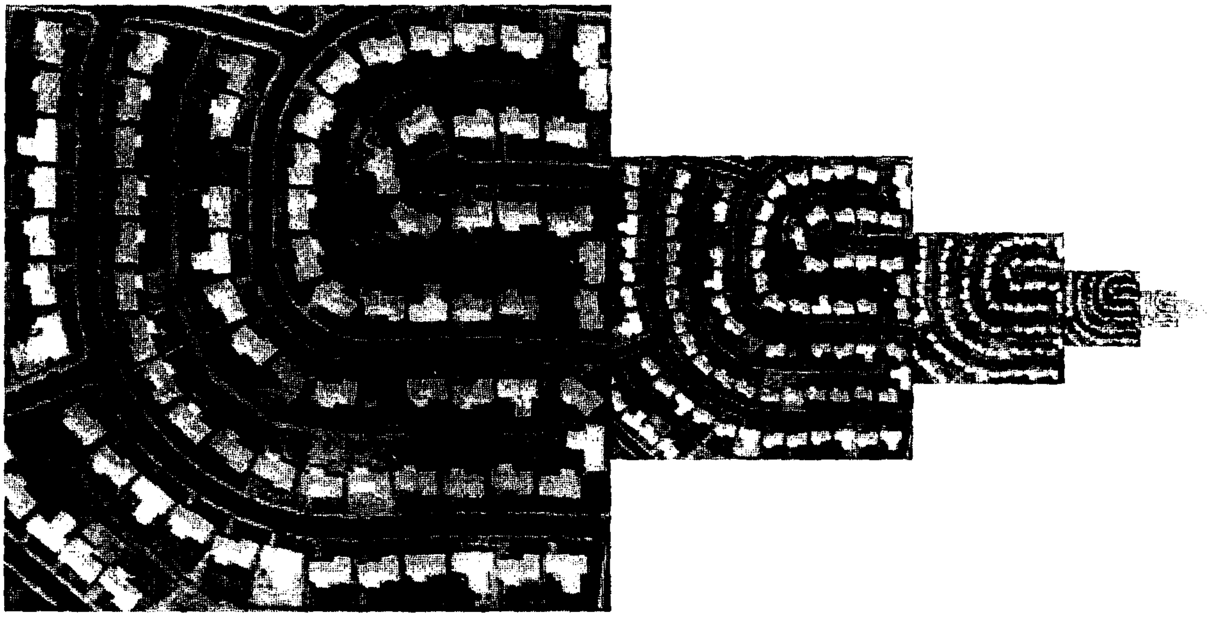


Figure 2: Gray-level pyramid of an urban scene

figure 2, whereas the lower part of figure 4 shows the direction response of the operator applied to the input image given in figure 2 (the direction values are coded as gray-levels).

3 Segmentation

3.1 Area-Oriented Segmentation

Dark or bright contrasting area-like segments are obtained by applying the area-oriented segmentation procedure. Input to the segmentation procedure are single dark or bright contrasting spots or sets of spots.

Segmentation is done by the following algorithm:

1. Select a dark/bright contrasting spot in level n of the spot-pyramid, so that strength and surroundedness responses of the selected spot are greater than a given threshold.

2. Project the selected spot from level n of the spot-pyramid to level $n + i$ of the gray-level pyramid.

3. Compute the meanvalue of the gray-level image within the projection area of the enlarged spot.

4. Take the computed meanvalue as a threshold and binarize the gray-level image within the patch (the N_8 neighborhood of the enlarged spot).

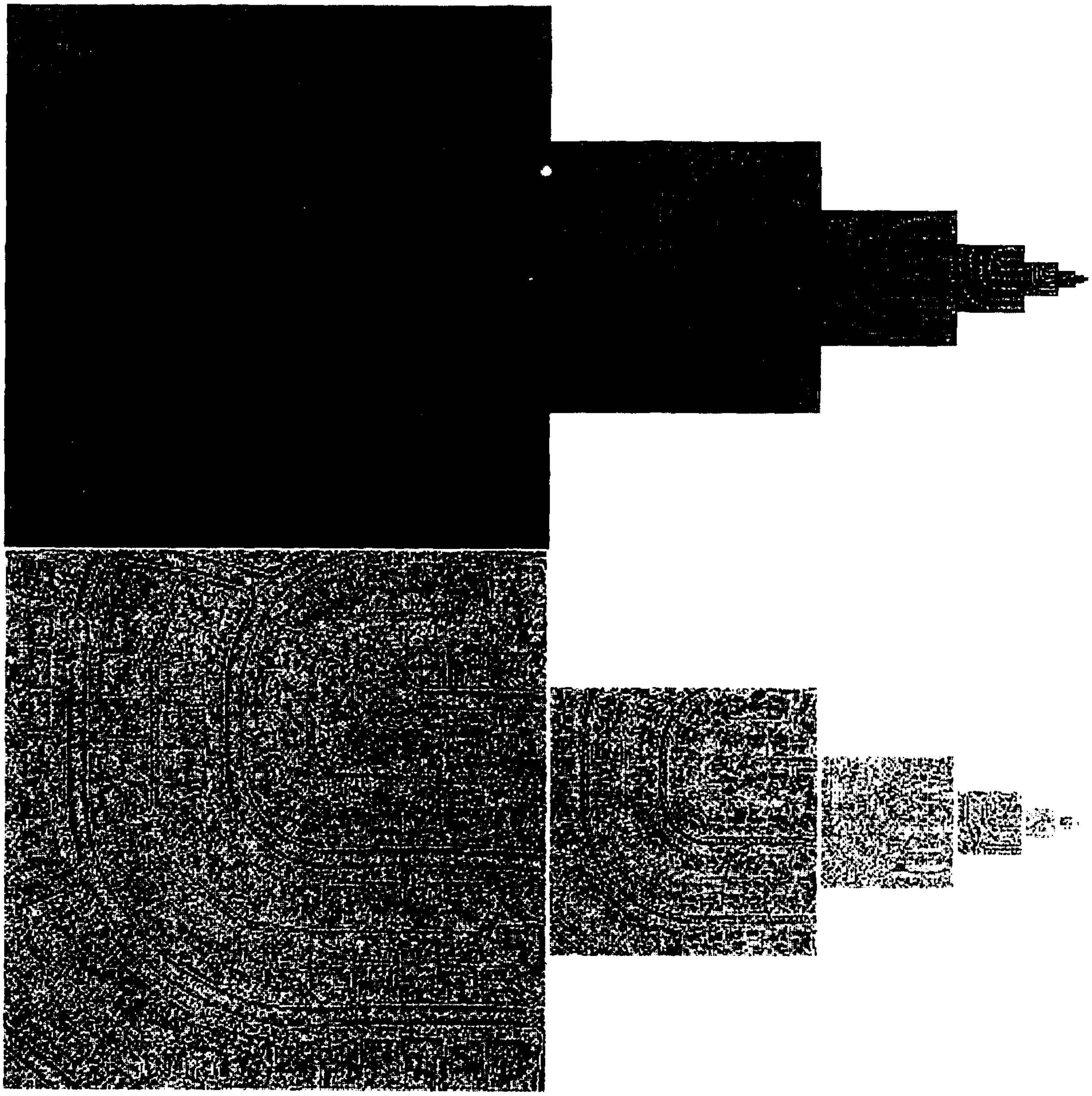


Figure 3: Spot-detector, strength (upper part), and surroundedness (lower part)

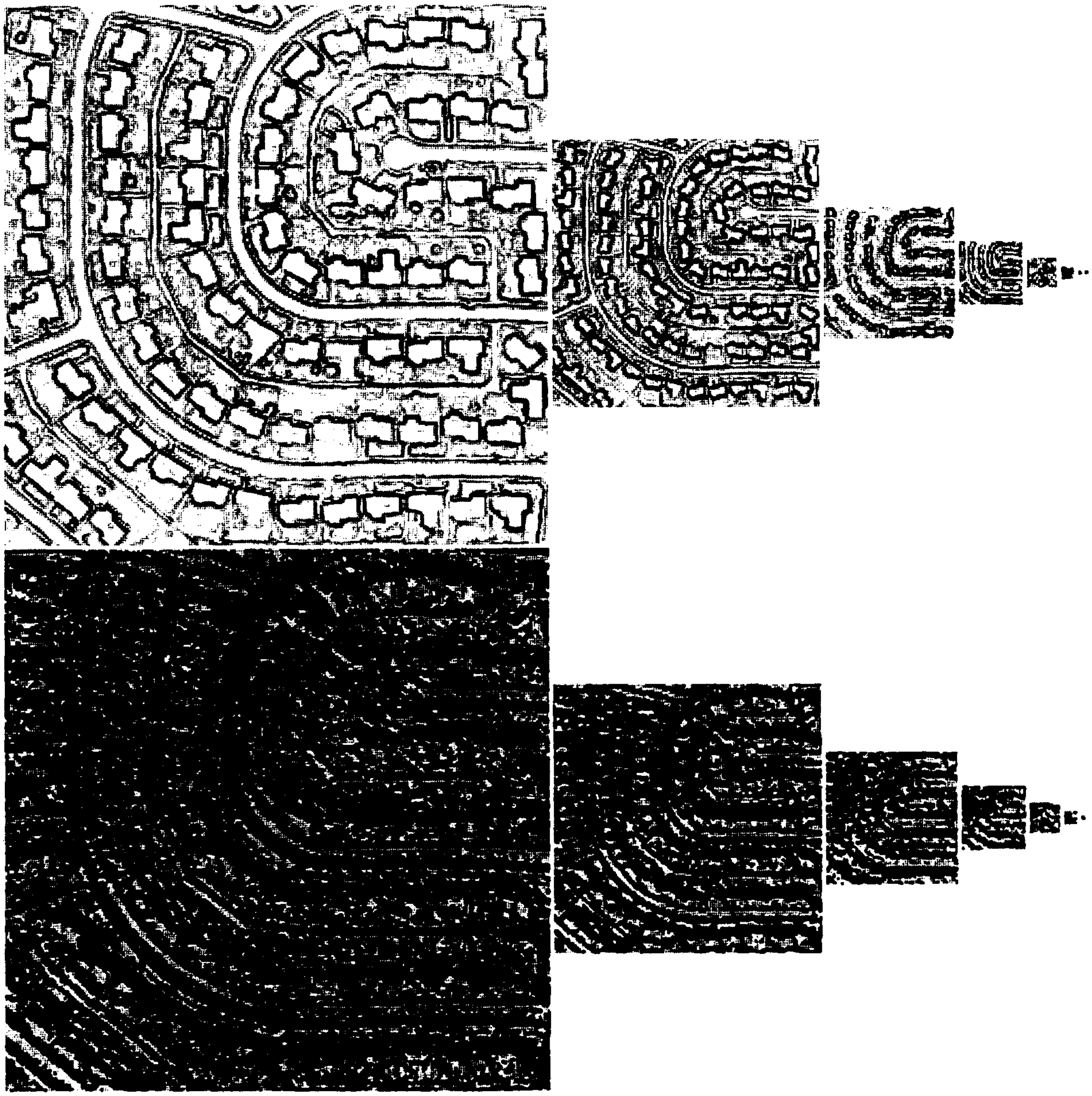


Figure 4: Edge-detector, strength (upper part), and direction (lower part)

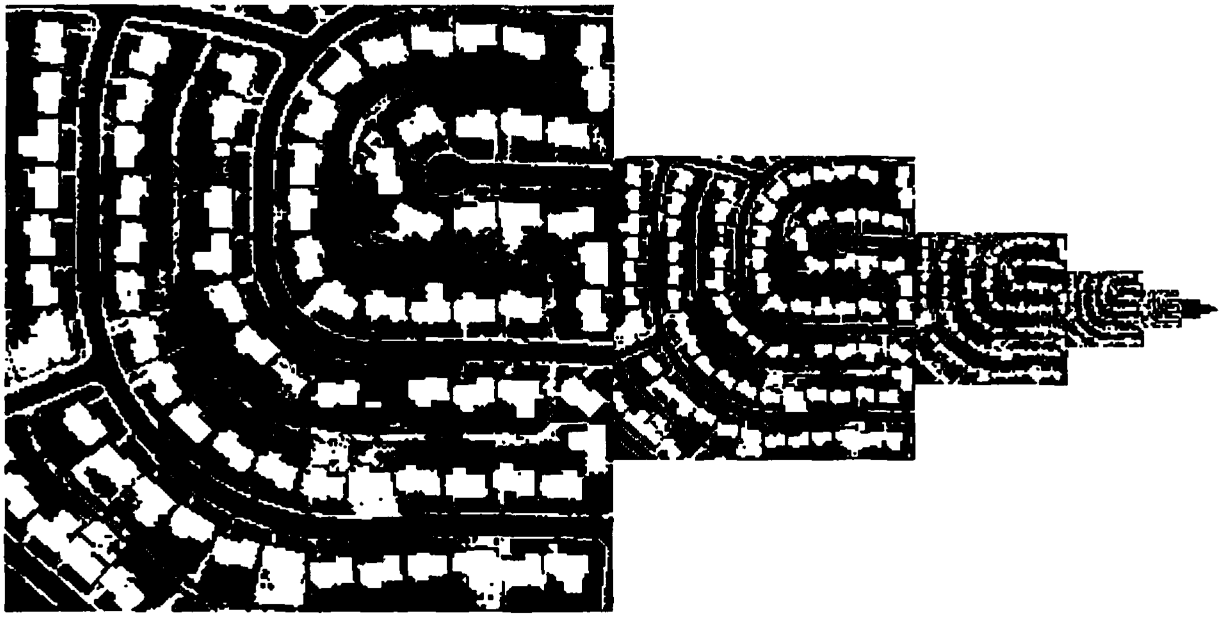


Figure 5: Area-oriented segmentation of bright contrasting spots

5. Compute additional features of the connectivity components of the patch.

6. Compute confidence values of the feature vectors of the connectivity components.

7. Threshold the confidence values of the feature vectors. Reject connectivity components with confidence values less than a given threshold. Accept components with confidence values greater or equal than a given threshold.

8. Store accepted components in the blackboard.

Figure 5 shows segmentation results received by projecting bright spots from level 3 of the spot-pyramid to levels $4,\ldots,8$ of the gray-level pyramid and applying the segmentation algorithm described above. Another example of applying the segmentation procedure is given in figure 6. Here the segments are obtained by projecting dark spots from level 3 of the spot-pyramid to levels $4,\ldots,8$ of the gray-level pyramid.

In the first case most of the bright contrasting houses are detected by the segmentation procedure. The segmentation of dark spots leads to the detection of dark contrasting segments, containing a great portion of the traffic network of the input image.

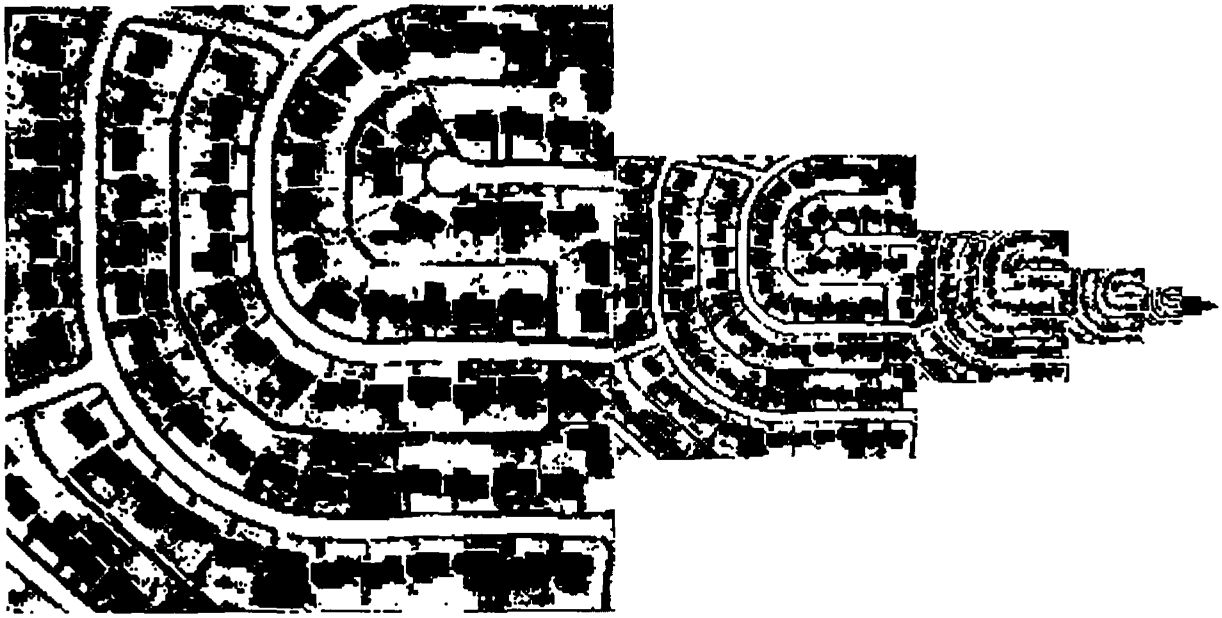


Figure 6: Area-oriented segmentation of dark contrasting spots

3.2 Edge-Oriented Segmentation

Edge-like segments are obtained by applying the edge-oriented segmentation procedure. Input to the segmentation procedure are edge elements computed by the Sobel operator.

Segmentation is done by the following algorithm:

1. Select an edge element in level n of the edge-pyramid, so that the strength response of the edge element is greater than a given threshold. This edge element is treated as the start element of the edge.

2. Look for adjacent predecessor/successor elements of the edge.

3. Test compatibility of the predecessor/successor elements with the current edge model.

4. Extend the edge with the most compatible predecessor/successor element.

5. If no compatible predecessor/successor element can be found, go to step 8.

6. Update the edge model.

7. Go to step 2.

8. Compute additional features of the edge.

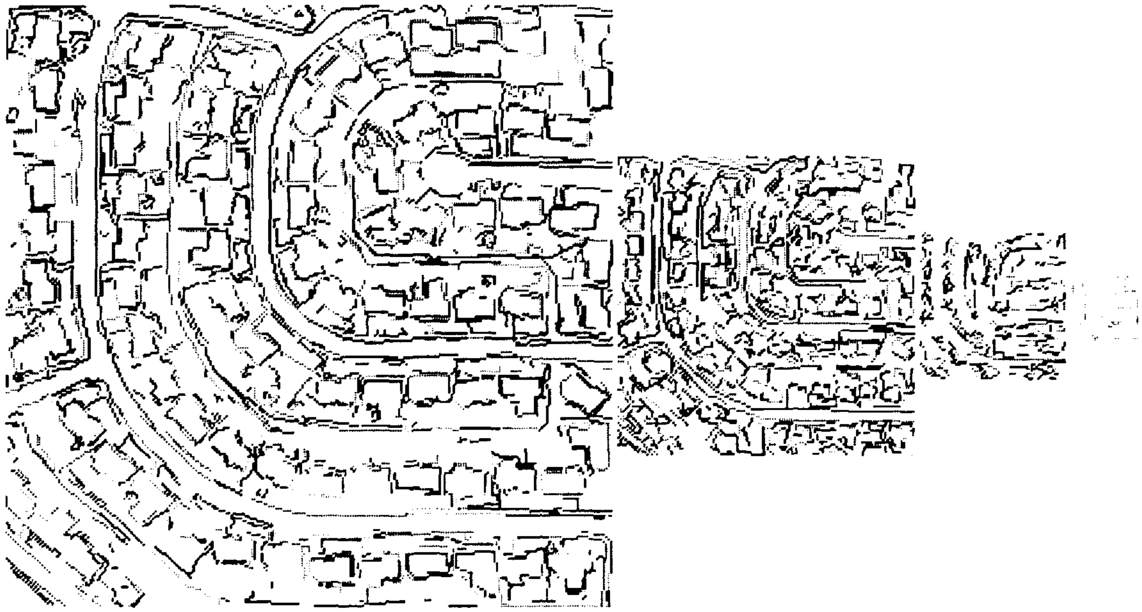


Figure 7: Edge-oriented segmentation

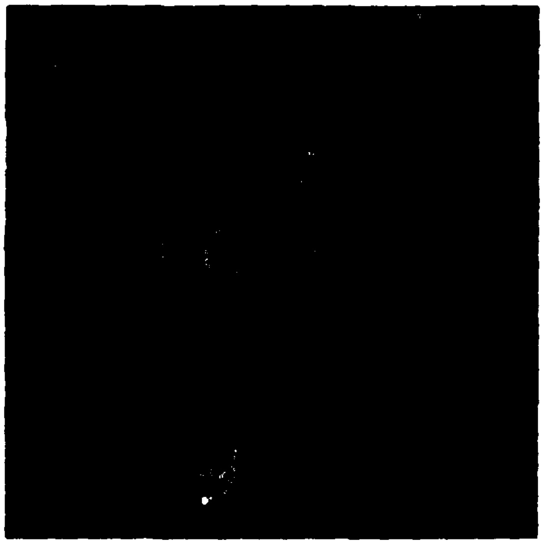
9. Compute confidence values of the feature vector of the edge.
10. Threshold the confidence values of the feature vector. Reject edges with confidence values less than a given threshold. Accept edges with confidence values greater or equal than a given threshold.
11. Store accepted edges in the blackboard.

Figure 7 shows segmentation results received by applying the segmentation procedure described above to levels $4, \ldots, 8$ of the gray-level pyramid. Most of the principal edges are detected by the edge-oriented segmentation procedure.

4 Blackboard-Oriented Production System

For analysing objects in images one can use syntactical classificators, which associate each object with a special class of account by analysing the structure of these image-objects. A special realization of that classificator is the blackboard-oriented production system for image understanding (BPI) implemented at FIM [4,5].

Starting with low-level elements (terminals) figure 8a, generated by picture preprocessing, the system generates more and more complex objects (nonterminales) up to the goal-object. To build more complex objects from less complex ones, the system has to test hypotheses about the objects. Each hypothesis is tested by a knowledge source of the blackboard-system. The generated



a)

b)

Figure 8: a) image with low-level elements, b) result from the classification of crossings

objects are stored in the blackboard memory for associative access. All knowledge sources are used in parallel to get all possible interpretations of the image. One object can be part of several more complex objects.

Figure 8a shows the input-image with the low-level elements included. In figure 8b results from the classification of crossings are shown.

Continuation of Work

Next topic to be done is to integrate existing low-level and medium-level algorithms into the blackboard-oriented environment. It is also necessary to test the performance of the blackboard-oriented approach with other images. Then the final phase of the contracted work should dedicated to the exploratory of the traffic network extraction in urban areas.

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Principal Investigator: Prof. Dr.-Ing. H. Kazmierczak,
FIM,
Ettlingen, Germany

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